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# GEOGRAPHICAL DISTRIBUTION OF AIR POLLUTANTS OVER THE SOUTHERN ONTARIO REGION

Report No. 90-137-K

M. Niewiadomski and K.S. Yoshiki-Gravelsins
Environmental Science Section
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## ABSTRACT

An environmental database which consists of monthly, seasonal and yearly averages of meteorological, air quality, precipitation chemistry, and emissions levels has been assembled. These data have been treated by contouring software to generate isopleths of pollutant concentrations over the southern Ontario region. The geographical distributions of key environmental parameters in atmospheric corrosion of transmission line conductors are discussed. In general, pollutant levels such as, $SO_2$ and calcium particulates in air, sulphate and chloride concentrations in precipitation and air, and temperature increase in the south westerly direction. Local maxima may be attributed to point source emissions; however, differences in levels between neighbouring environmental monitoring stations may also depend on the period of study and long term variability in pollutant concentration.



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## EXECUTIVE SUMMARY

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**M. Niewiadomski and K.S. Yoshiki-Gravelsins**
**Environmental Science Section**
**Chemical Research Department**

Assembly of a complete environmental database is necessary in order to assess the atmospheric corrosivity of sites in Ontario. These environmental assessments or ratings can be utilized in Ontario Hydro's transmission line refurbishment programme to predict lifetimes of conductors and other transmission system components. Meteorological, air quality, precipitation chemistry, and emissions data have been assembled from various existing databases. The geographical distributions of pollutant levels have been determined by analysis of data using NCAR software. Although some analyses are limited by lack of data or insufficient geographical representation, the results, in general, provide valuable information. Contour plots over the southern Ontario region of environmental parameters critical to atmospheric corrosion of transmission line conductors are presented in this report. These include levels of $SO_2$ and calcium particulates in air, pH of precipitation, relative humidity, temperature, and chloride, sulphate and ammonia concentrations in precipitation. Point source emissions and wind parameter data which may be used in future, pollutant dispersion modelling studies, are also provided.



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# GEOGRAPHICAL DISTRIBUTION OF AIR POLLUTANTS OVER THE SOUTHERN ONTARIO REGION

## 1.0 INTRODUCTION

An integral part of Ontario Hydro's transmission line refurbishment programme [1] is the investigation of atmospheric corrosion of ACSR transmission line conductors and hence, the assembly of a complete environmental database for the southern Ontario region. Recent studies [2,3,4] have identified not only key factors responsible for corrosion of conductors (eg, $SO_2$, $SO_4^{2-}$ and $Cl^-$ in precipitation) but also the need for data at locations between environmental monitoring stations. In order to enable future, comprehensive correlation studies between degree of corrosion and air pollutant levels, and as a first step towards preparing the 'pollution climatology' of southern Ontario, an environmental database has been assembled from meteorological, air quality, precipitation chemistry and emissions data. An analysis of these data, focusing on geographical distribution of pollutant levels, has been performed using NCAR contouring software. The details of the environmental database, results of the analysis, and the importance of various environmental factors in atmospheric corrosion of transmission line conductors, are discussed in this report.

## 2.0 ENVIRONMENTAL DATABASE

Available meteorological, air quality, precipitation chemistry and emissions data have been assembled for the southern Ontario region. Geographical distributions of these data are presented in the form of isopleths of yearly average levels, using an NCAR graphics package [5]. The complicated task of plotting contours for irregularly distributed data has been performed by CONRAN utility. CONRAN 'triangulates' data and then imposes a dense, 'virtual' grid, in which each point is assigned a value interpolated from neighbouring data points. It should be noted that, especially in the case of sparse data, contours vary depending on the resolution of the virtual grid and the interpolation method used. Also, the algorithm of CONRAN produces several obvious artifacts, as evidenced near the south east border of the plot area.

The contour plots include data values which are printed horizontally and are to be distinguished from contour labels. Results of statistical treatment (number of data points, maximum, minimum and mean values, standard deviation) of data within the mapped area, are displayed at the top of each figure. The range of contour values and the contour interval are given along the bottom of the plot, as well. The sections which follow give discussion of salient features of particular fields within the environmental database.

## 2.1 Meteorological Conditions

The meteorological database has been assembled from the 'Digital Archive of the Long Term Monthly Normals', available through the Canadian Climate Centre of A.E.S. Average environmental levels have been computed over periods of 10 to 30 years, ending in 1980. The environmental parameters: relative humidity, speed and direction of wind, temperature, and total precipitation, are presented as monthly, seasonal and yearly averages. The number of sites reporting these data are 34, 44, 379, and 505, respectively - several locations are given in Figure 1.

### 2.1.1 Relative Humidity

The relative humidity field, shown in Figure 2, exhibits an average yearly maximum (79.4 %) north of Kitchener, and minima in the Toronto (71.8 %) and Ottawa (70.3%) areas. The average relative humidity level is highest during the winter months (December to February) and lowest during spring (March to May); monthly values exceed 80% in fall and winter. The "time of wetness", which can be defined as the amount of time that the relative humidity exceeds a critical value for surface wetness, might be a better parameter to consider in cause-effect relationships of atmospheric corrosion. A relationship for the critical relative humidity as a function of dew point above 0°C is available for galvanized steel in contact with hygroscopic salts [6].

### 2.1.2 Wind

Seasonal and yearly average wind speeds and directions are available in the environmental database. Although drying of conductors following precipitation is related to wind speed, wind direction and duration at threshold speeds are more applicable to transport of air pollutants and dispersion modelling studies. Geographical distributions of wind parameters are not presented in this report.

### 2.1.3 Temperature

Figure 3 shows that the average mean temperature increases in the southerly direction, as expected. A region of lower temperature can also be seen north of Kitchener which coincides with the region of high relative humidity in Figure 2. Although increasing temperature has the effect of increasing surface tension as well as ionic conductivity, both of which enhance corrosion of metals, a loss in electrolyte due to evaporation also occurs. Studies have shown that the corrosion rate of zinc in moist air (relative humidity > 80%) reaches a maximum around -2°C [7].

### 2.1.4 Precipitation

The level of precipitation enhances line corrosion by introducing moisture and dissolving passivating product layers; however, dissolution of corrosive species is also effected. Yearly totals of precipitation in mm are displayed in Figure 4.

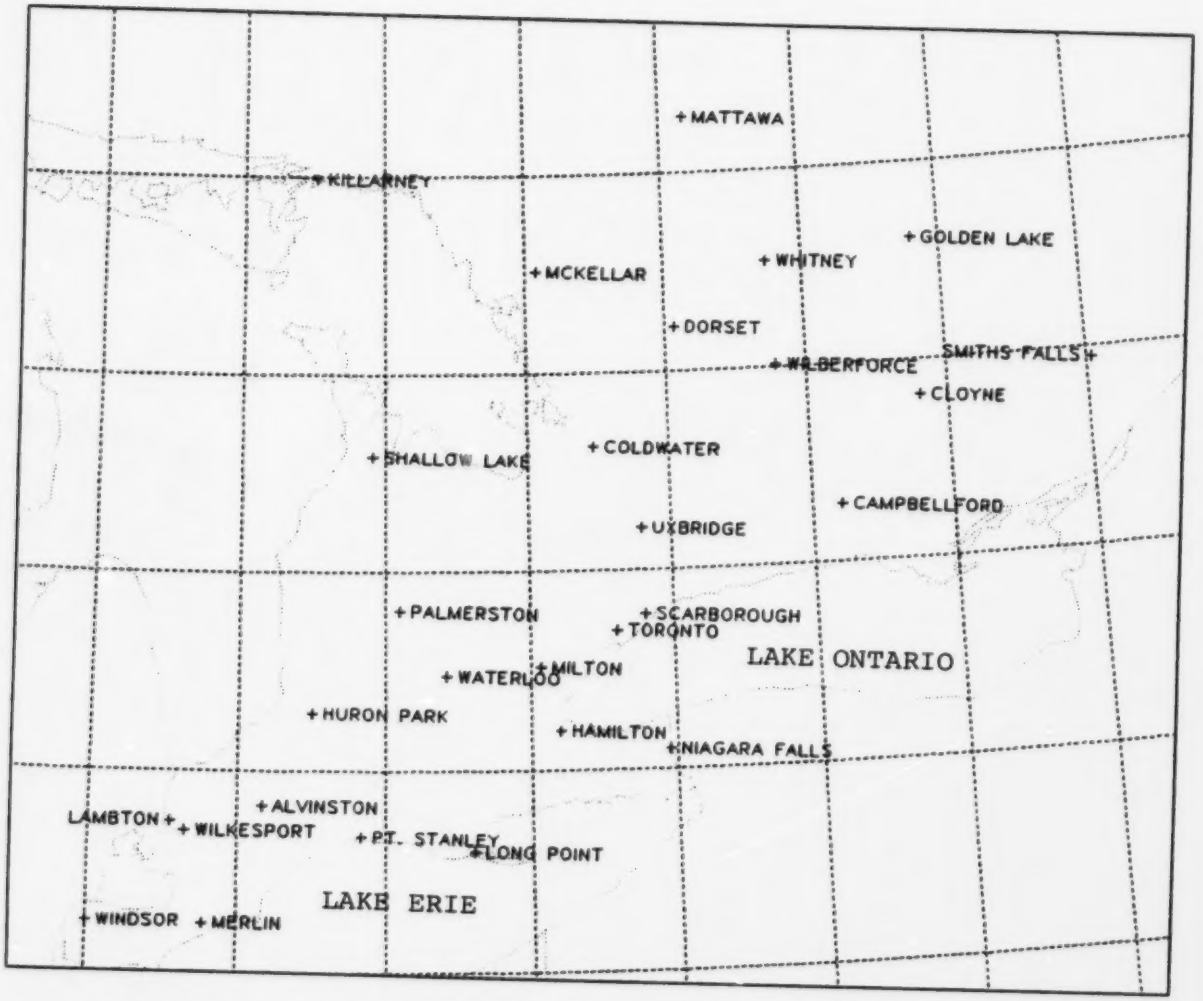



Figure 1 Locations of Environmental Monitoring Stations

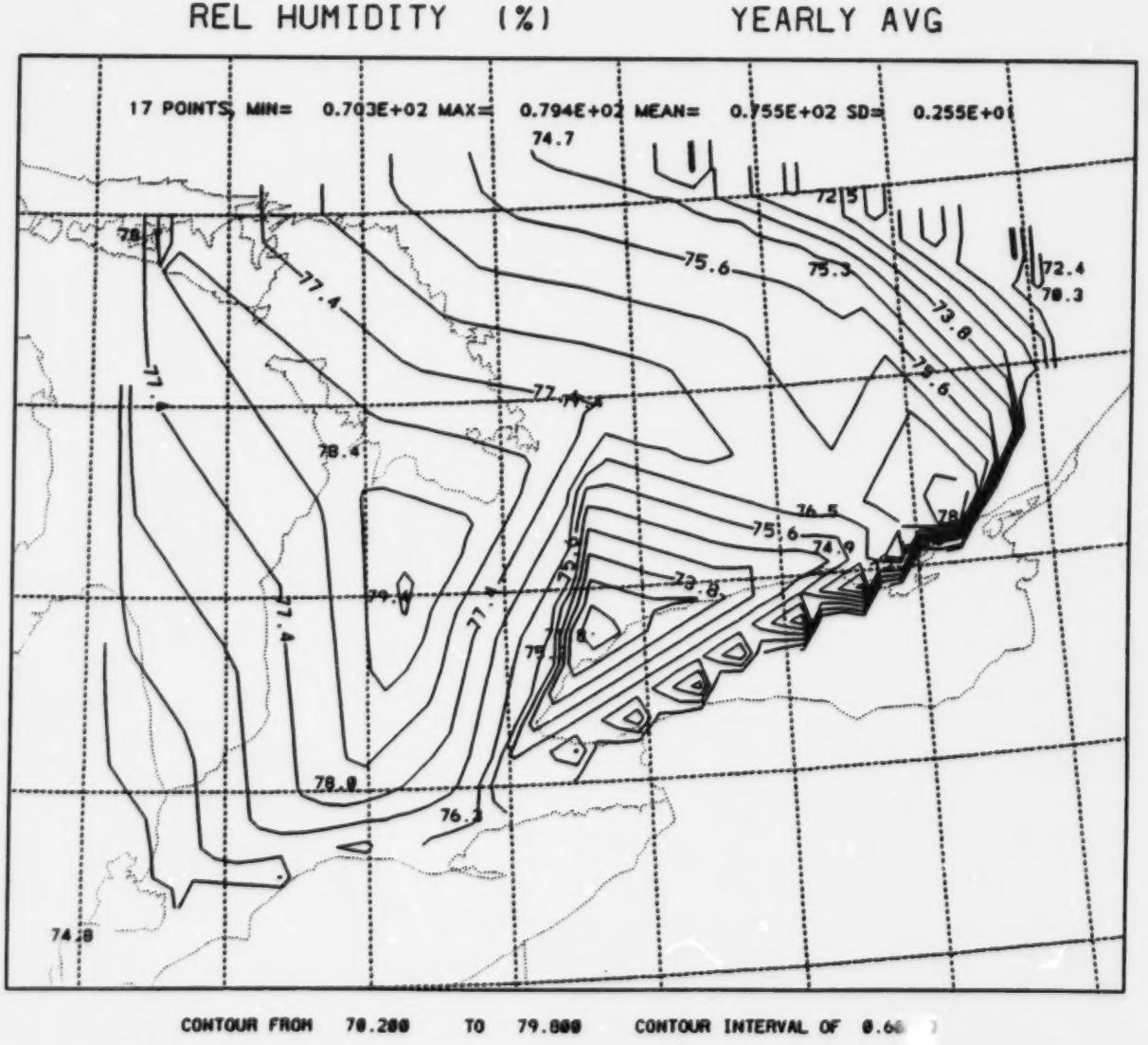



Figure 2 Contour Lines of Yearly Average Relative Humidity Levels (%)

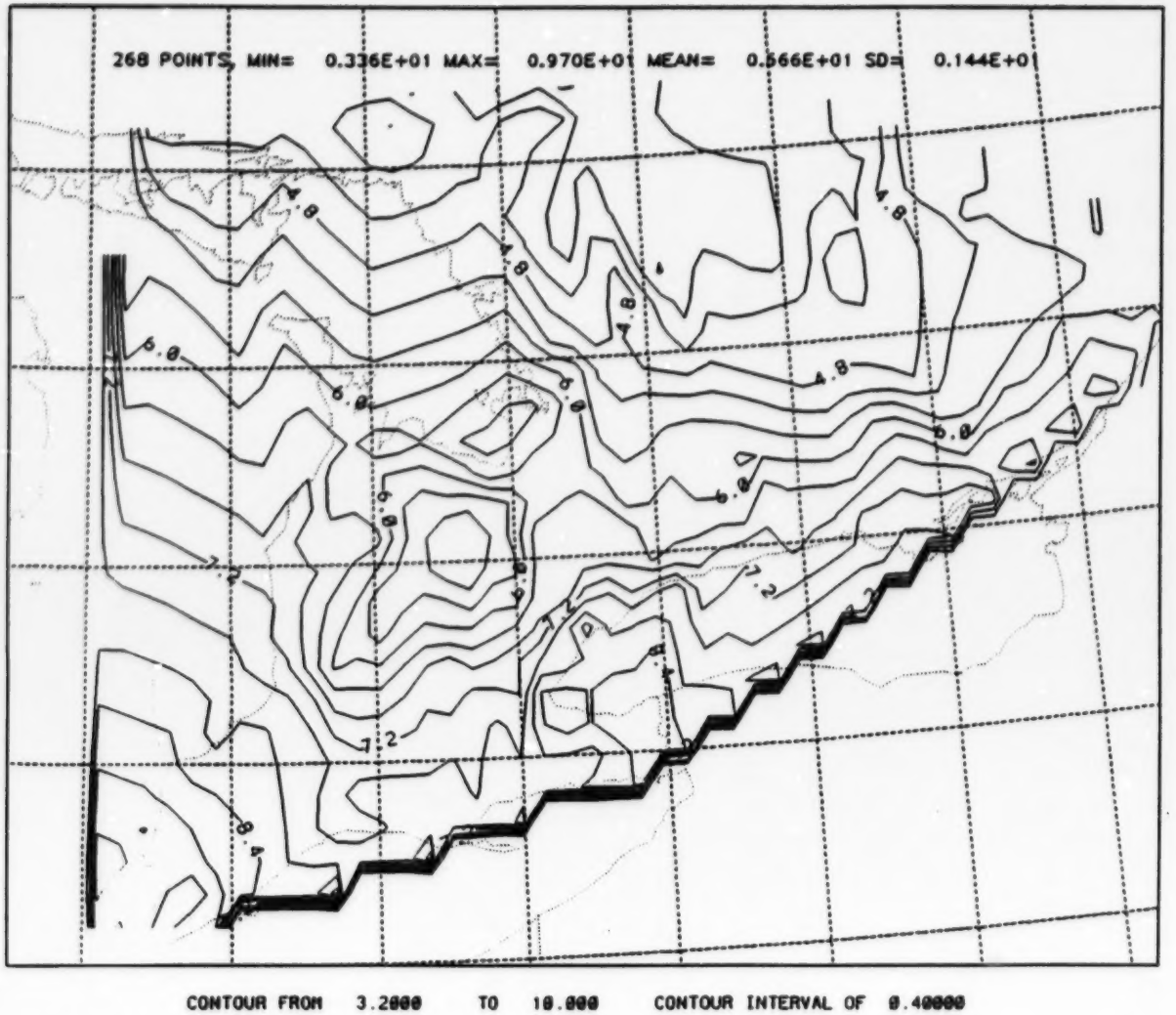

DAY TEMP (C)
YEARLY AVG
268 POINTS, MIN= 0.336E+01 MAX= 0.970E+01 MEAN= 0.566E+01 SD= 0.144E+01
CONTOUR FROM 3.2000 TO 10.000 CONTOUR INTERVAL OF 0.40000

Figure 3 Contour Lines of Yearly Average Temperature Levels ($^{o}$C)

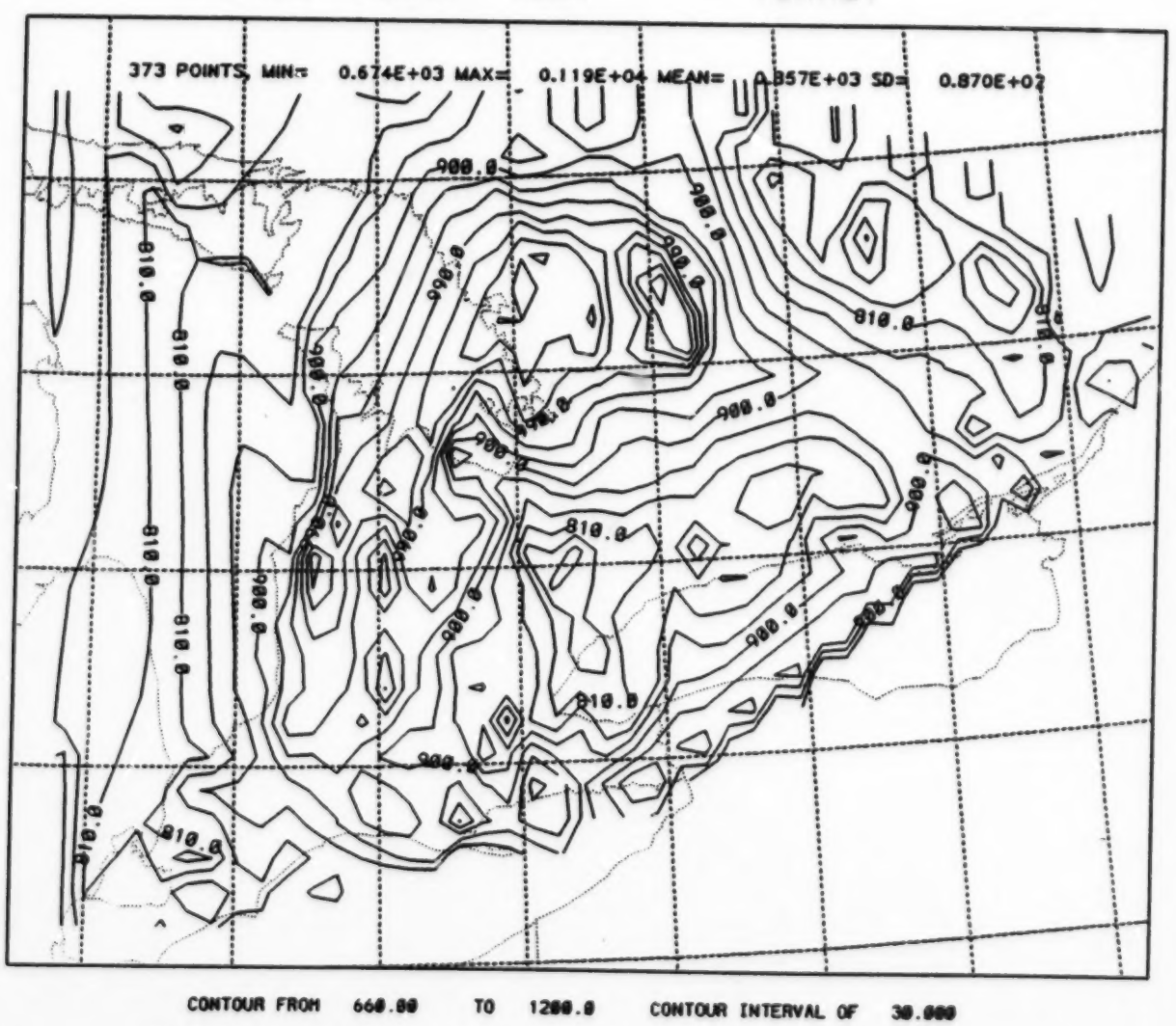

TOTAL PRECIP (mm) YEARLY
373 POINTS, MIN= 0.674E+03 MAX= 0.119E+04 MEAN= 0.857E+03 SD= 0.870E+02
CONTOUR FROM 660.00 TO 1200.0 CONTOUR INTERVAL OF 30.000

Figure 4 Contour Lines of Yearly Average Total Amounts of Precipitation (mm)

## 2.2 Air Quality

Air quality data consist of yearly and seasonal average concentrations of $SO_2$, NO, $NO_2$, $NO_x$, total reduced sulphur (TRS), total suspended particulates (TSP), and ozone. These data were collected during the late seventies and early eighties to 1985, at 123 locations in Ontario, through the Air Quality Monitoring Program (AQM) of the Ontario Ministry of the Environment (see [8] for a general description of the programme). Limited data from the 1950's and 1960's are also available. The air quality monitoring stations are concentrated in urban centres. In some instances, neighbouring stations were treated as one (eg, 8 locations in Windsor), using an average value, for the purpose of analysis by the contouring software.

This section also includes air pollutant data ($SO_2$, sulphate, nitrate and chloride) measured during the Acidic Precipitation in Ontario Study (APIOS, see Section 2.3), by the Ontario Ministry of the Environment. Fields of pollutants most likely responsible for atmospheric corrosion of transmission line conductors are discussed below.

### 2.2.1 $SO_2$

Sulphur-bearing corrosion products have been identified on aluminum and galvanized steel surfaces exposed to rural and industrial environments [4]. The $SO_2$ contour plot, shown in Figure 5, includes data from both the Air Quality Monitoring Program (AQM) and the Acidic Precipitation in Ontario Study (APIOS). $SO_2$ concentration generally increases in the south westerly direction; however, high levels are visible in the Hamilton/Toronto/Niagara area. There are a few significant differences in concentration between neighbouring stations, eg, 2.0 ppb and 23.3 ppb (obscured) in Scarborough, which may result from local conditions, different study periods, and long term variability in $SO_2$ concentration.

### 2.2.2 $NO_x$

Yearly and seasonal averages of NO, $NO_2$, and $NO_x$ levels in air are available in the environmental database. Since the presence of nitrates in the corrosion layers of aluminum and zinc has not been confirmed [9,10], the fields are not presented in this report.

### 2.2.3 Suspended Particulates

Data of total suspended particulates (TSP) have not been analyzed by the contouring software since only a limited number of sites (6) are available. The number of monitoring stations and geographical distribution for constituent particulates (sulphates, chlorides, nitrates) through the APIOS study is more extensive. Yearly sulphate concentration in air ($\mu g/m^3$) is presented in Figure 6. Similar to $SO_2$ distribution, high levels are in the south west region, and the highest seasonal values are in summer.

Chlorides, similar to sulphates, are recognized as corrosion stimulators [9]. The geographical distribution of yearly average chloride concentrations in air is illustrated in Figure 7. Concentration increases in the south westerly direction, and the highest seasonal values are in winter, presumably in response to extended levels of coal burning and use of road salt.

Nitrate levels in air have not been analyzed, as discussed in Section 2.2.2.

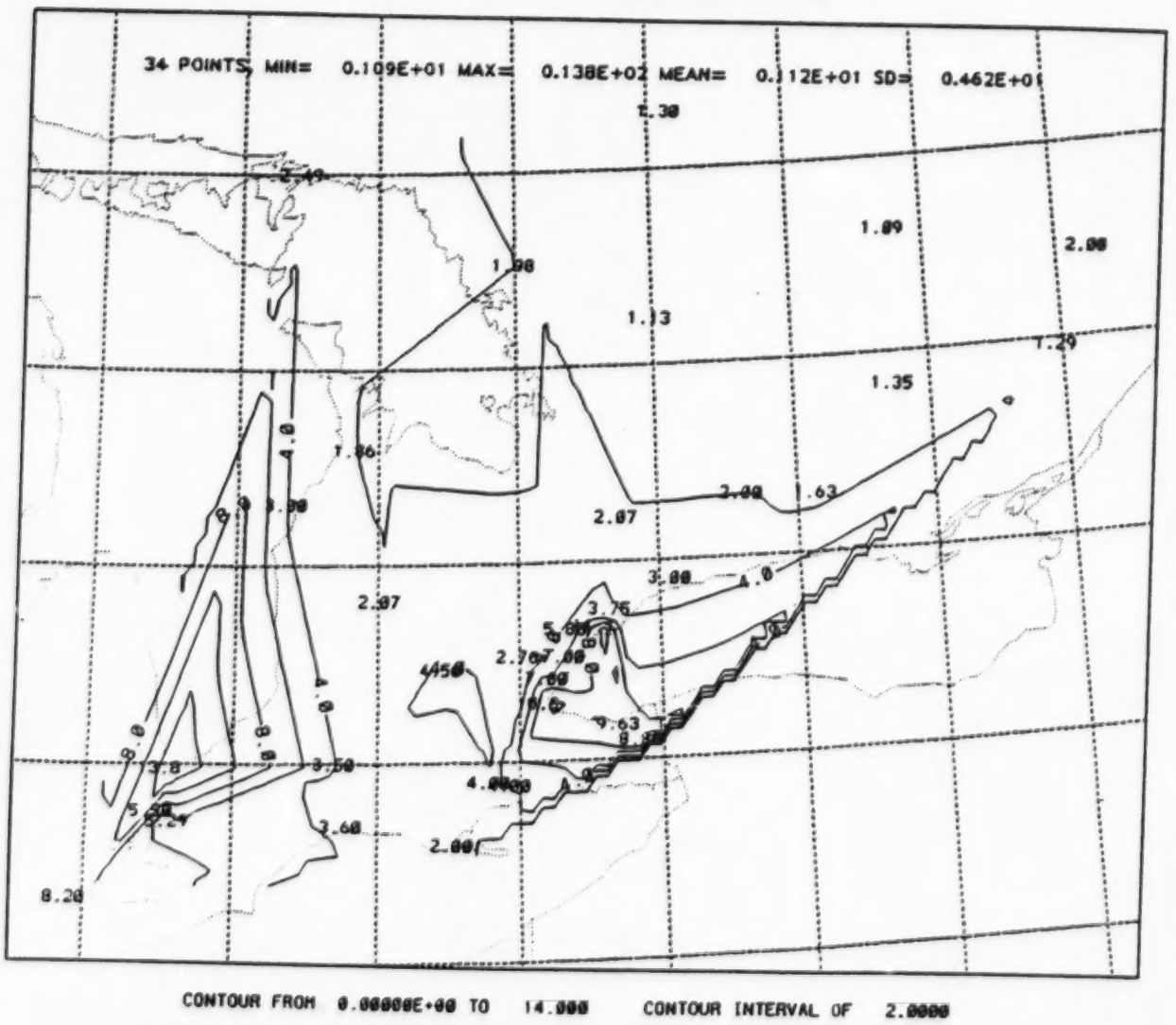

SO2PPB YEARLY AVG
34 POINTS, MIN= 0.109E+01 MAX= 0.138E+02 MEAN= 0.112E+01 SD= 0.462E+01
CONTOUR FROM 0.00000E+00 TO 14.000 CONTOUR INTERVAL OF 2.0000

Figure 5 Contour Lines of Yearly Average $SO_2$ Concentrations in Air (ppb)

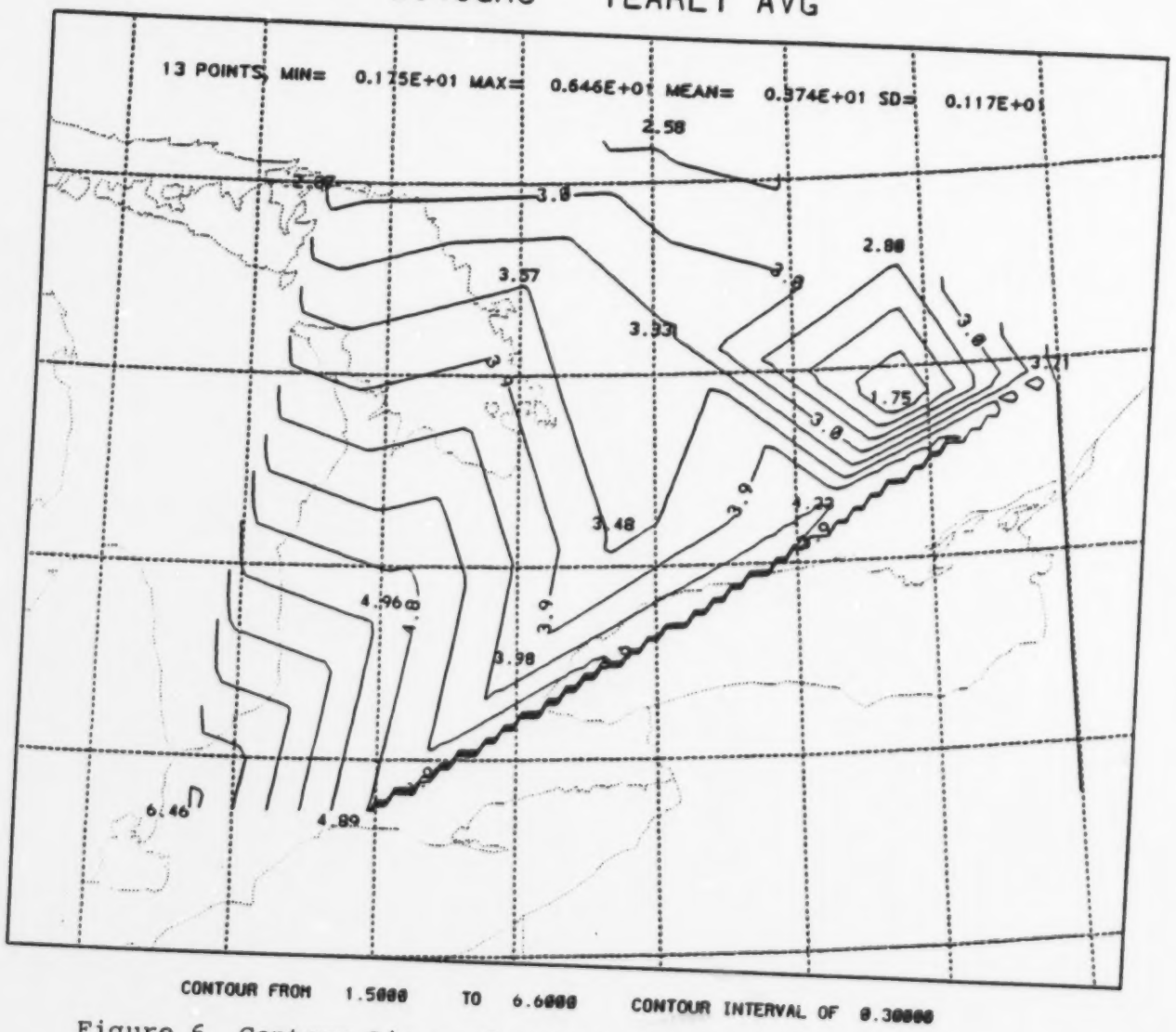



Figure 6 Contour Lines of Yearly Average Sulphate Concentrations in Air ($\mu g/m^3$)

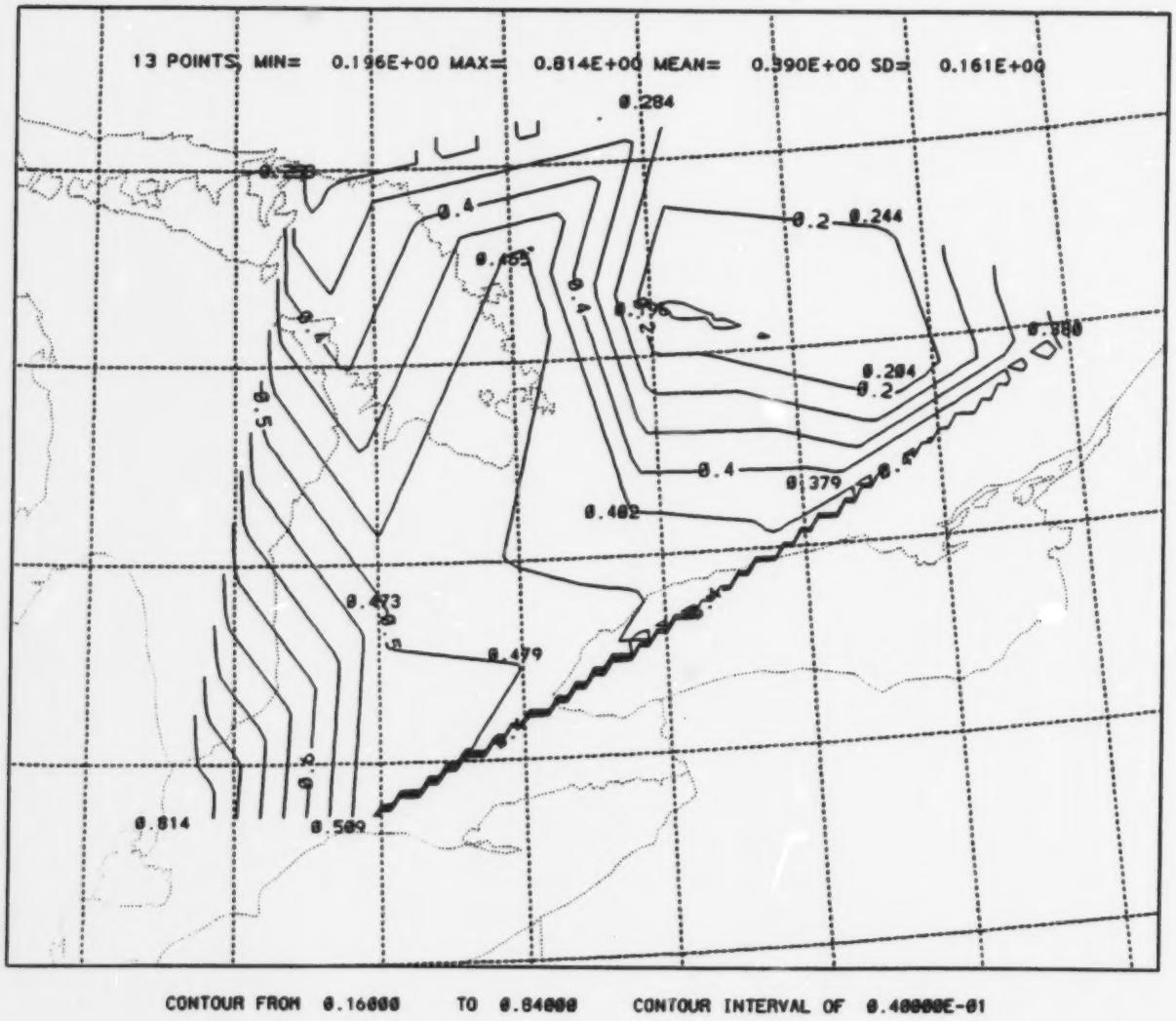



Figure 7 Contour Lines of Yearly Average Chloride Concentrations in Air ($\mu g/m^3$)

Calcium concentrations in air are shown in Figure 8. Levels increase in the south westerly direction, and a maximum is apparent around Campbellford. Particulates may participate in the corrosion process by (i) acting as cathodes in differential oxygen (aeration) cells; (ii) introducing corrosion stimulators, such as calcium chloride, to the metal surface; and, (iii) increasing the ionic conductivity of the moisture film.

### 2.2.4 Ozone

Contour lines of ozone levels have not been plotted due to the limited number of monitoring stations and lack of sufficient geographical distribution of data points. In general, lower values are observed in the winter months and a yearly minimum covers the Toronto area.

## 2.3 Precipitation Chemistry

Pollutant concentrations in precipitation ($SO_4^{2-}$, $Cl^-$, $NO_3^-$, $NH_4^+$, free $H^+$, Fe, Mn, etc.) were measured during the Acidic Precipitation in Ontario Study through the Ontario Ministry of Environment [11,12], at 37 stations across Ontario, between 1980 and 1986. This study also includes some pollutant levels in air which were addressed in Section 2.2, Air Quality.

### 2.3.1 Sulphates

It is believed that $SO_4^{2-}$ species participate in the corrosion of transmission line conductors by adsorbing to oxide-covered aluminum surfaces and by increasing the ionic conductivity of the moisture film. The concentrations of sulphate ions in precipitation are shown in Figure 9. Although values increase generally in the south westerly direction, local maxima are apparent around Guelph to Milton and near Cloyne (see Figure 1 for locations). Highest levels occur in spring and summer.

### 2.3.2 Chlorides

The pitting of metals, namely aluminum, is associated with chloride ions. $Cl^-$ concentrations in precipitation are shown in Figure 10. The contour pattern resembles that for sulphate ions in precipitation, with the exception that high $Cl^-$ values occur in winter and spring.

### 2.3.3 Nitrates

The field of nitrates in precipitation is similar to those for sulphate and chloride ions; however, since there is no evidence that nitrates initiate corrosion of conductor surfaces, the plot is not presented in this report.

### 2.3.4 Ammonia

Solutions of ammonia are known to have low surface tensions, and thus, exhibit good wetting properties [13]. The yearly average concentrations of $NH_4^+$ in precipitation, displayed in Figure 11, indicate maxima in the Guelph and Campbellford areas, as well as higher values during spring and summer.

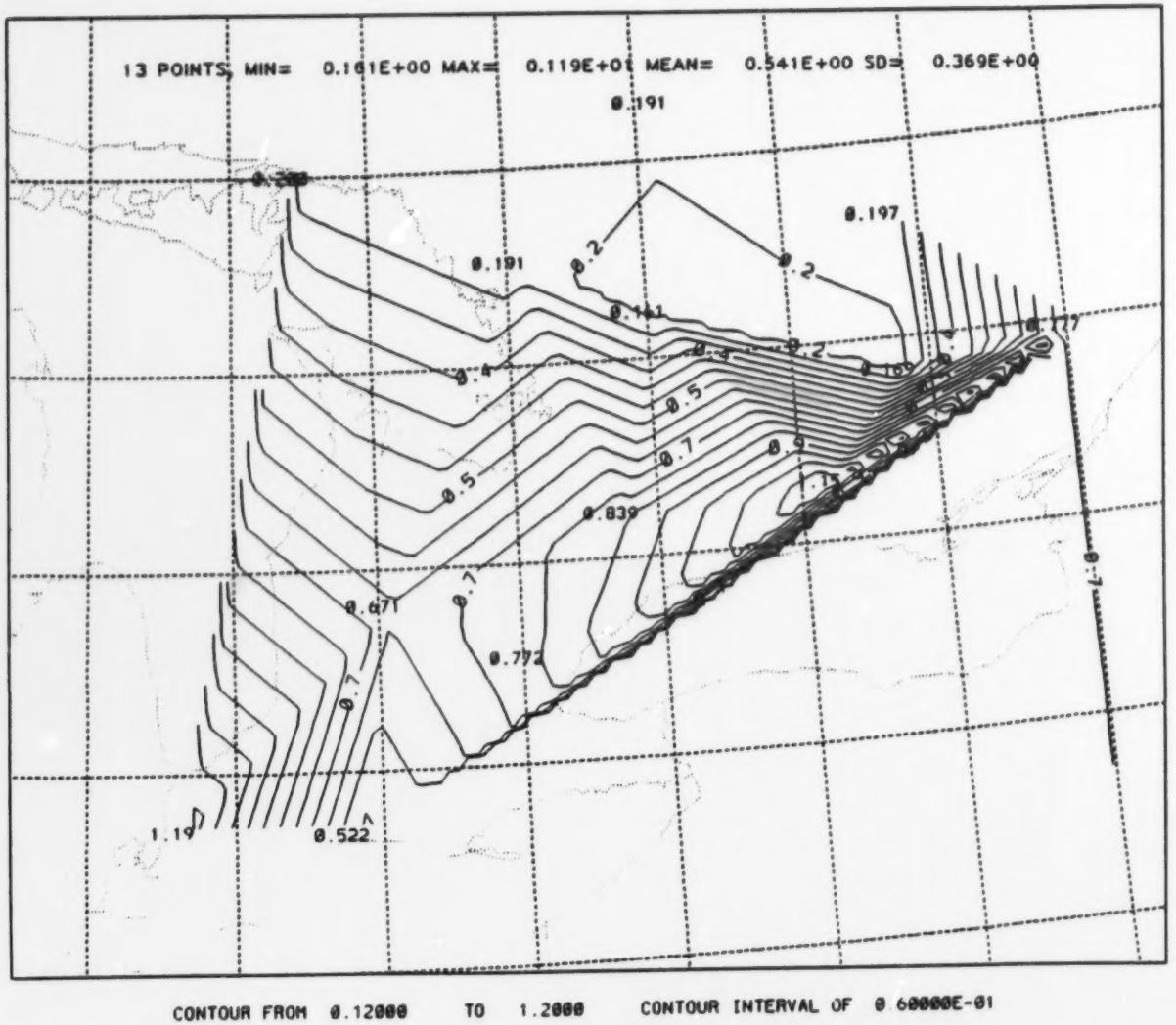



Figure 8 Contour Lines of Yearly Average Calcium Concentrations in Air ($\mu g/m^3$)

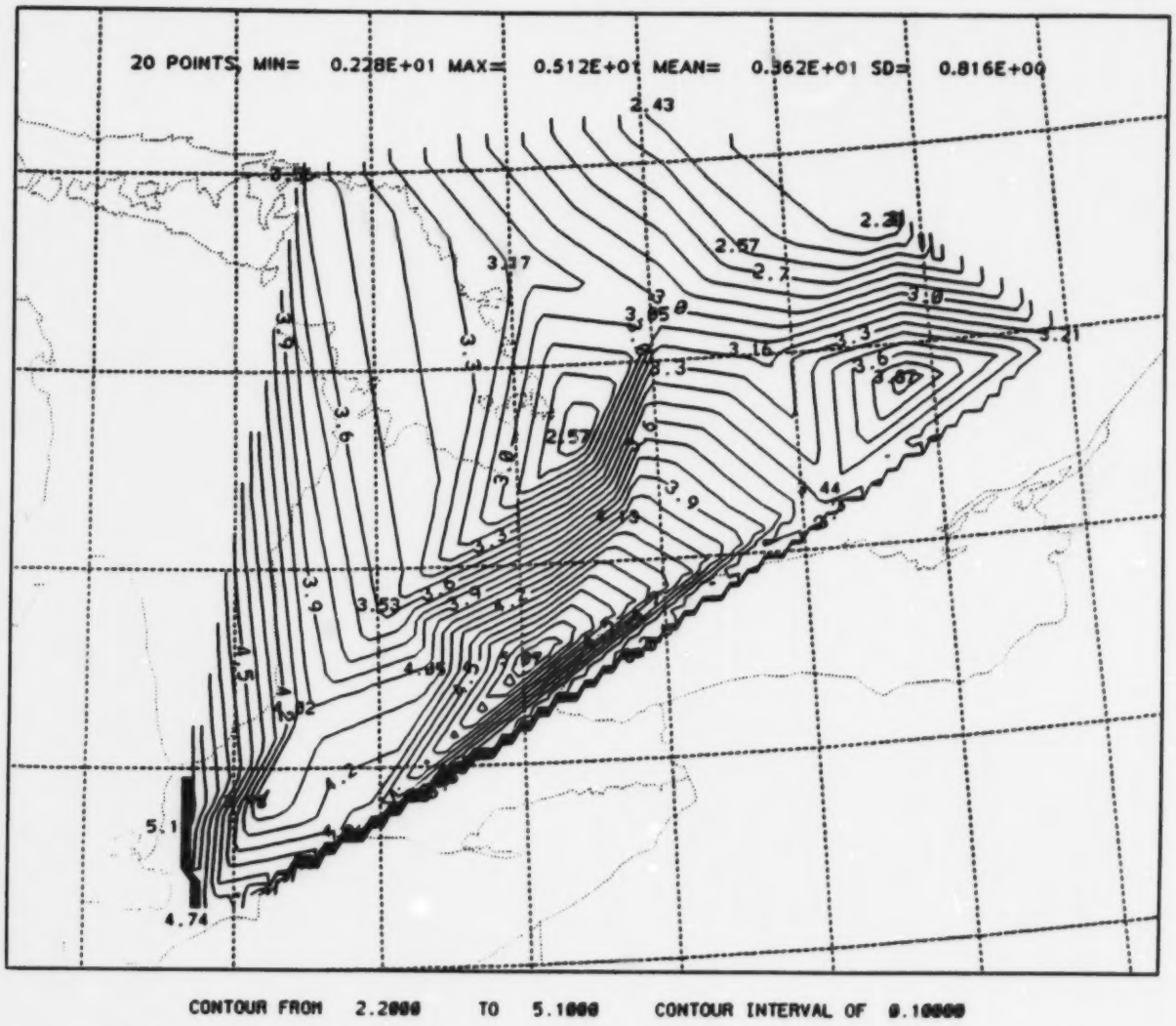

SO4MGL YEARLY AVG
20 POINTS MIN= 0.228E+01 MAX= 0.512E+01 MEAN= 0.362E+01 SD= 0.816E+00
CONTOUR FROM 2.2000 TO 5.1000 CONTOUR INTERVAL OF 0.10000

Figure 9 Contour Lines of Yearly Average Sulphate Concentrations in Precipitation (mg/L)

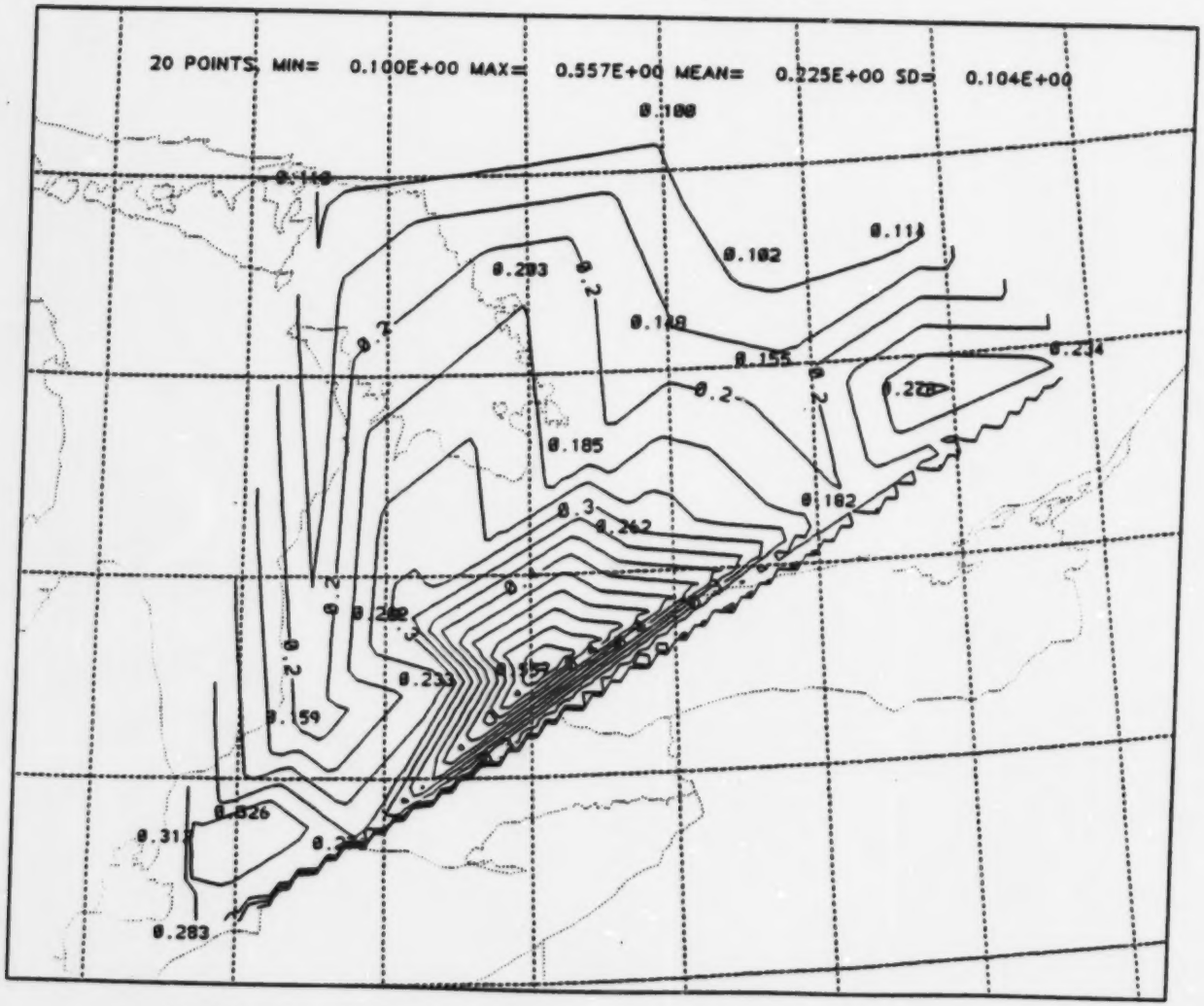



Figure 10 Contour Lines of Yearly Average Chloride Concentration in Precipitation (mg/L)

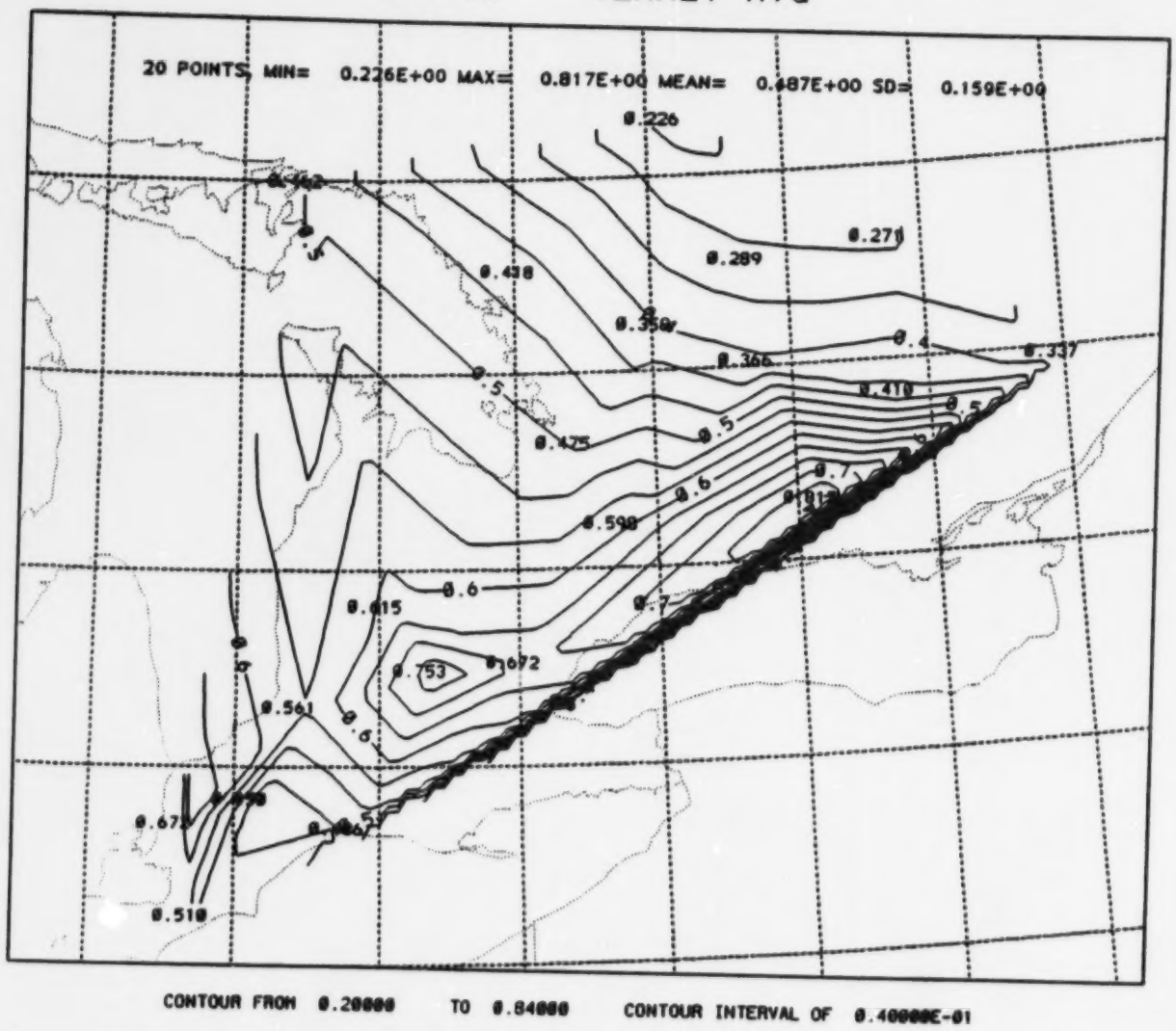



Figure 11 Contour Lines of Yearly Average Ammonia Concentrations in Precipitation (mg/L)

### 2.3.5 pH

The range of pH over the southern Ontario region is 4.07 to 4.69, indicating acidic precipitation. The geographical distribution of yearly average pH in precipitation is shown in Figure 12. Acidic conditions enhance corrosion by affecting the stability of passivating corrosion product layers, such as carbonates [10].

### 2.3.6 Trace Metals

The catalytic effect of iron and manganese, in chemical reactions involved in aluminum and zinc corrosion, has been reported in the literature [14]. These metals are present, in general, only in trace amounts (0.024 to 0.22 mg/L); however, higher iron and manganese concentrations are found in the south western region of Ontario.

## 2.4 Point and Area Emissions

Yearly emissions in tonnes of $SO_2$, $NO_x$, particulates, CO and volatile organic compounds (VOC), from sources in Ontario, have been obtained from the Ontario Ministry of the Environment. Point and area emissions per UTM grid square have been reported. UTM grid cells range in area from 5x5km to 10x10km in southern Ontario, to 100x100km in some remote areas of the province. Point and area emissions for most pollutants are similar outside urban centres. Major point sources of $SO_2$, exceeding 2000 tonnes per year (see Figure 13), are located in Sudbury (695 000 t/year) followed by Hamilton and Sarnia. $NO_x$ and particulate point source emissions are greatest in Lambton and area source emissions are greatest over Toronto. Concentrated CO and VOC emissions are reported over the Toronto/Hamilton area.

# 3.0 APPLICATIONS OF THE ENVIRONMENTAL DATABASE

## 3.1 Environmental Corrosion Index

A preliminary correlation between age of conductor at the time of 32% RTS strength loss and air pollutant levels [3] indicated the need for more complete environmental data, especially between monitoring stations, and the need to consider combined pollutant effects (eg, amount of precipitation and $SO_2$ concentration). The environmental database, presented in this report, will be useful in the development of an algorithm which considers key atmospheric pollutants and corresponding threshold levels. In this way, a single parameter representing the atmospheric corrosivity of a location (environmental corrosion index), can be determined. Index ratings which may be correlated to useful conductor life can be assigned to sites over the Ontario region. These results will be instrumental in meeting objectives of the transmission line refurbishment program, ie, establishing schedules and priorities for introduction of replacement lines and novel overhead line designs.

## 3.2 Dispersion Modelling Studies

The importance of point and line source emissions has been illustrated in this report. Thus, dispersion modelling studies to predict pollutant levels in the vicinity of sources (eg, highway, lime plant) and in areas remote from environmental monitoring stations will be useful in determining environmental corrosion indices, described above.

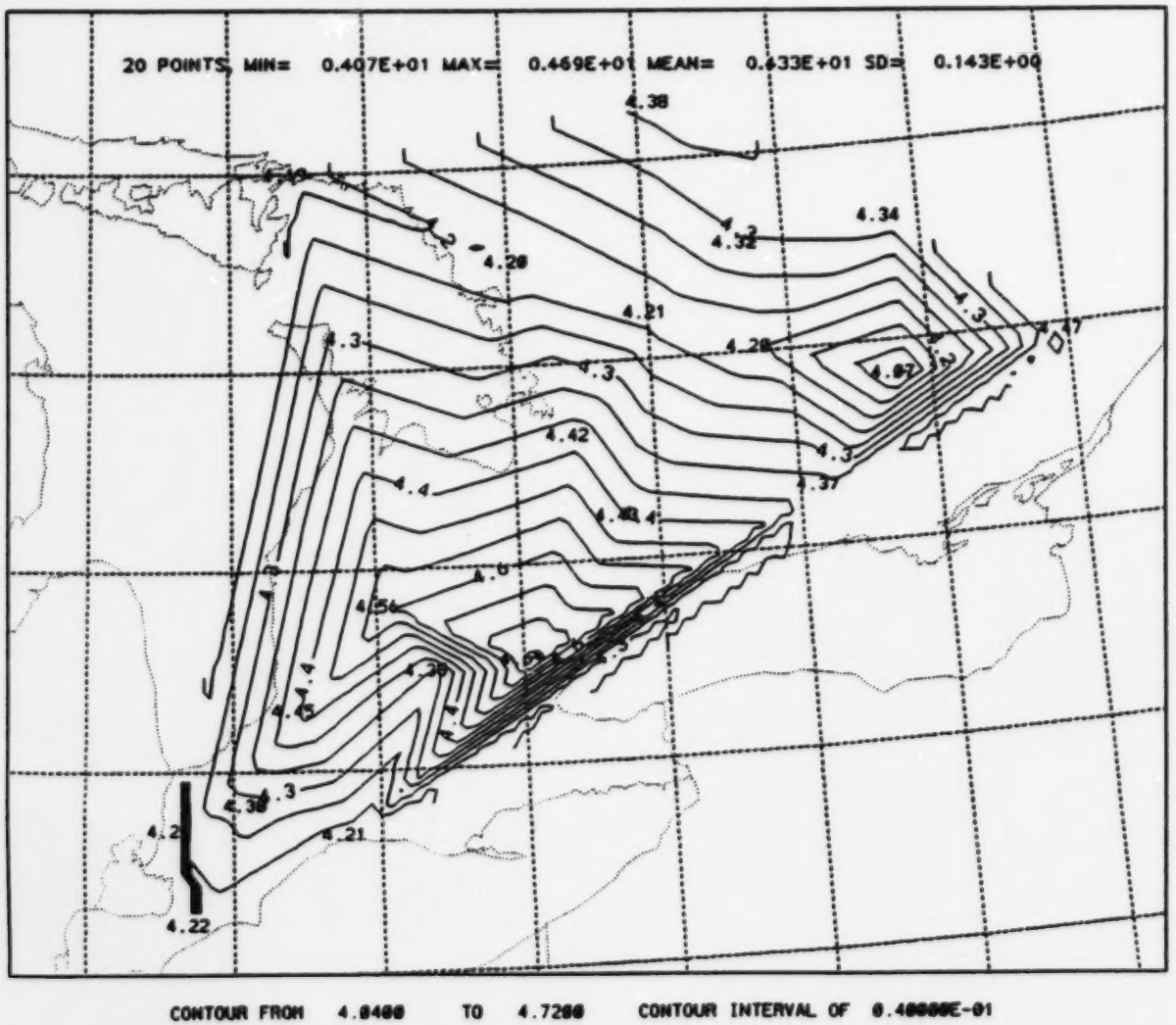



Figure 12 Contour Lines of Yearly Average pH Levels in Precipitation

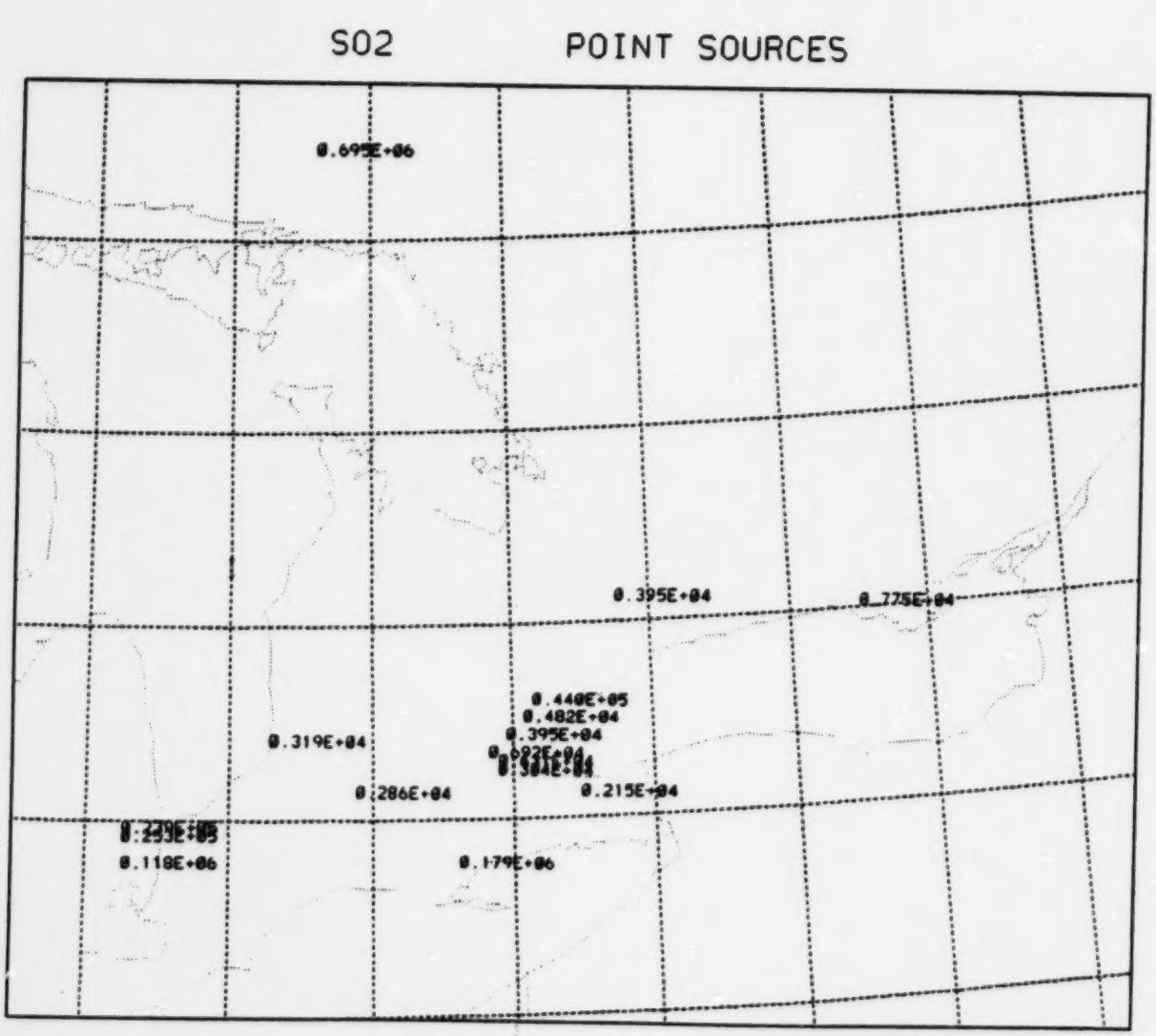


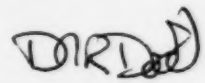

Figure 13 Point Source Emissions of $SO_2$ in Air Exceeding 2000 tonnes/year

## 4.0 SUMMARY

An environmental database has been assembled which consist of monthly, seasonal and yearly averages of meteorological, air quality, precipitation chemistry, and emissions levels. Unlike the other parameters, air quality monitoring (AQM) stations are concentrated in urban centres, and hence, analysis of these data by contouring software is rather limited. Contour patterns vary depending on the resolution of the virtual grid and the interpolation method used in the analysis, especially in the case of sparse data. In addition, there are a few significant differences in pollutant levels between neighbouring stations which may be attributed to local conditions, different study periods, and long term variability in pollutant concentration.

Despite these shortcomings, the environmental database provides valuable information for the corrosion studies of transmission line conductors. Geographical distributions of sulphate, chloride and ammonia levels in precipitation, calcium particulates in air, and $SO_2$ will be particularly useful in determining environmental corrosion index ratings for sites across Ontario. Furthermore, emissions and wind parameter data will provide information which can be used in dispersion modelling studies.

Approved by:



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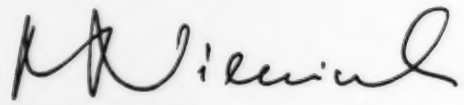

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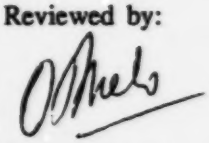

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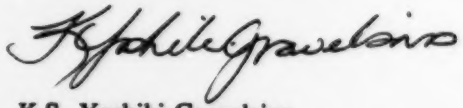

K.S. Yoshiki-Gravelsins
Engineer
Environmental Science Section

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